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Supplement
NOTS TP 3163
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**MODIFICATIONS AND ADDITIONS TO THE NOTS GENERAL
OPTICAL RAY TRACING COMPUTER PROGRAM**

SUPPLEMENT

by

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MAY 14 1963

ABSTRACT. Additional modifications to the general optical ray tracing computer program at NOTS are presented. This material is supplemental to NAVWEPS Report 7966 (NOTS TP 3011), dated September 1962.

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FOREWORD

Additional modifications and changes in the NOTS general optical ray tracing computer program are reported. This material supplements that appearing in NAVWEPS Report 7966 (NOTS TP 3011) of the same title, and is intended for use with that report. It has been reviewed for technical accuracy by John R. Snyder.

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INTRODUCTION

Previous modifications and additions to the NOTS General Optical Ray Tracing Computer Program were reported in NAWEPs Report 7966 (NOTS TP 3011). Since the publication of that report, the following additional changes have been made in the ray tracing program.

MODIFICATIONS AND ADDITIONS TO ABERRATIONS

The equation for Petzval sum has been changed from

$$PTZ = - \sum_{i=1}^m \left(\frac{N'_{10} - N_{10}}{N'_{10} N_{10}} \right) c_i, \text{ to}$$

$$PTZ = - \sum_{i=1}^m \left(\frac{N'_1 - N_1}{N'_1 N_1} \right) c_i$$

Since another aberration has been added to the first eight already computed, another ray must be traced with the first nine rays. This ray, numbered 9A, is the marginal sagittal ray. The aberration XSR, the distance from the focal plane to the intersection point of the marginal sagittal rays, is given by the equation

$$XSR = -T'_{z9A} \frac{q'_{x9A}}{q'_{z9A}}$$

Ray number 9A and the aberration XSR are shown in Fig. 1.

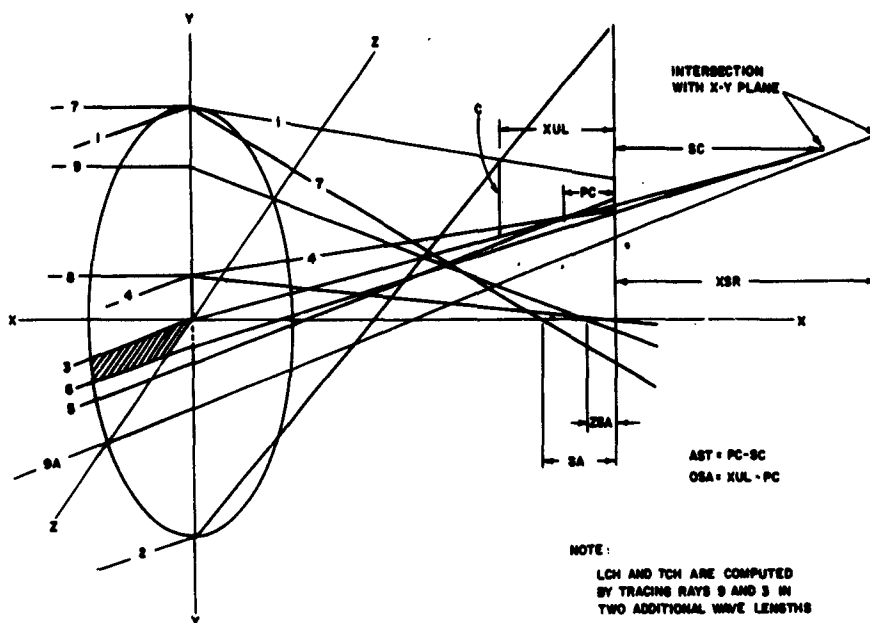


FIG. 1. Aberration Diagram.

TRACING THROUGH ASPHERIC CYLINDRICAL INTERFACES

The equation for the interface is

$$f(x, y, z) = A (-y \sin \alpha + z \cos \alpha)^8 + B (-y \sin \alpha + z \cos \alpha)^6 \\ + C (-y \sin \alpha + z \cos \alpha)^4 + D (-y \sin \alpha + z \cos \alpha)^2 - x = 0$$

where A, B, C, D are the aspheric coefficients, α is the angle between the axis of the cylinder and the positive x-y plane (the positive direction of rotation for α is from the positive x-y plane to the positive x-z plane), and $x, y, z = T'_x, T'_y, T'_z$, respectively. The equation for the ray is

$$\frac{x - T_x}{q_x} = \frac{y - T_y}{q_y} = \frac{z - T_z}{q_z}$$

therefore, $y = \frac{q_y}{q_x} (x - T_x) + T_y$ and $z = \frac{q_z}{q_x} (x - T_x) + T_z$

where $T_x = T'_x(1-1) - \frac{q_x}{q_x} t_1$; $T_y = T'_y(1-1)$; $T_z = T'_z(1-1)$.

$$\begin{aligned} \text{Now } f(x) = & A \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^8 \\ & + B \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^6 \\ & + C \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^4 \\ & + D \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^2 \\ & - x = 0 ; \end{aligned}$$

and

$$\begin{aligned} f'(x) = & 2 \left(-\frac{q_y}{q_x} \sin \alpha + \frac{q_z}{q_x} \cos \alpha \right) \left\{ 4A \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^7 \right. \\ & + 3B \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^5 \\ & + 2C \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right]^3 \\ & \left. + D \left[\left(-\frac{q_y}{q_x} (x - T_x) - T_y \right) \sin \alpha + \left(\frac{q_z}{q_x} (x - T_x) + T_z \right) \cos \alpha \right] \right\} \\ & - 1 = 0. \end{aligned}$$

To solve $f(x)$ for x , the Newton-Raphson method is used. Once x is found, y and z can be found from the ray equation.

The partial derivatives of the interface equation are

$$H_x = -1$$

$$H_y = -2 \sin \alpha [4A(-y \sin \alpha + z \cos \alpha)^7 + 3B(-y \sin \alpha + z \cos \alpha)^5 \\ + 2C(-y \sin \alpha + z \cos \alpha)^3 + D(-y \sin \alpha + z \cos \alpha)]$$

$$H_z = 2 \cos \alpha [4A(-y \sin \alpha + z \cos \alpha)^7 + 3B(-y \sin \alpha + z \cos \alpha)^5 \\ + 2C(-y \sin \alpha + z \cos \alpha)^3 + D(-y \sin \alpha + z \cos \alpha)]$$

where H_x must have the same sign as q_x . Now use equations 96-107 of "Ray Tracing Through Uncentered and Aspheric Surfaces", by William A. Allen and John R. Snyder, OPT SOC AM, J, Vol. 42, No. 4, pp. 243-249, April 1952, reprinted as the appendix to NAWEPS Report 7966 (NOTS TP 3011), pp. 26-32.

AN ADDITION TO AUXILIARY PROGRAM NO. 20501

The square lattice input for spot diagram computation program has been modified so that spot diagrams may be computed automatically for cylindrical interfaces. The equation for the number of points, N_p , inside the rectangular pupil is

$$N_p = \left(\frac{L + W}{2\delta} + 1 \right)^2$$

Solving for the increment, δ , we have

$$\delta = \frac{L + W}{2(\sqrt{N_p} - 1)}$$

where L and W are the length and width, respectively, of the cylindrical interface as shown in Fig. 2. No obstruction is permitted for spot diagrams for cylindrical interfaces.

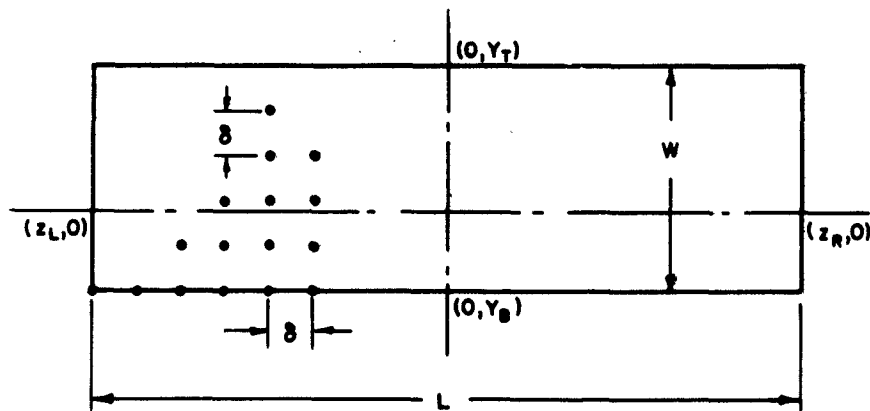


FIG. 2. Square Lattice for Cylindrical Lens Spot Diagram Computation.

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